REMARKS

I. Status of the Application

In the Office Action mailed March 13, 2006, the Examiner objected to the drawings due to certain informalities, including a requirement that certain claim features be shown in the drawings, and the redundant use of a reference character "100". The Examiner also objected to page 26 of the specification due to an error in the description of a figure. The Examiner objected to claims 13 and 18 due to informalities relating to improper construction. The Examiner rejected claims 1-4, 6, 8-9, 25-28 and 30 under 35 USC § 102(b) as being anticipated by US Patent 6,161,210 to Chen *et al.* ("Chen"), and rejected claims 13-22 and 24 as being anticipated by the reference "Algorithm-based low-power and high-performance multimedia signal processing" by Liu ("Liu"). The Examiner also rejected claims 5, 7, 10, 12, 23 and 29 under 35 USC § 103 based on either the Chen or Liu references in combination with one or more of US Patent 6,070,263 to Tsui ("Tsui"), the reference "A Transformation for Computational Latency Reduction in Turbo-MAP decoding" to Raghupathy, and the reference "High-performance VLSI architecture for the Viterbi Algorithm" to Boo ("Boo").

Applicants herein have amended the figures, specification and claims, and respectfully request reconsideration in view of the following remarks.

II. Summary of the Invention

The methods and systems described in the application involve identifying candidate paths through a state trellis based on a group of observed data, where each candidate path corresponds to a best path through a trellis beginning at one of a possible set of prior states,

and then selecting one of the paths based on candidate sequence selection information, which is typically prior state decisions (e.g., data symbols in the form of one or more bits). The path selection, in turn, provides decoding of symbols and data bit information for use in selecting one of the candidate paths in a subsequent stage. Because the identification of candidate paths is independent of the prior state decision(s), the system advantageously performs much of the necessary path metric calculations or path selection before the decision(s) regarding the prior state(s) is available. Thus, the current state decision(s) may be made immediately once the prior state decision(s) are made available.

The candidate paths are identified from groups of paths, where the groups are formed based on the initial state in the trellis or code. In this regard, the groups correspond to all of the possible valid paths or sequences emanating from the particular initial state(s) associated with the group. In the preferred embodiments of the apparatus, the groups are formed implicitly by virtue of the hardware configuration. Thus, the groups are predetermined, being formed *a priori* and independently from any observed data. When the data or observations are then obtained, and the error metrics are determined, a candidate path is identified from each group, where the candidate path is the best path of the predetermined group that is based on the observed data. Finally, the prior decision information is used to identify the prior state, which in turn implicates one of the predetermined groups, for which there is now only one candidate path remaining. The selection of that candidate path, in turn, is translated into decoding decisions.

It should be understood that the preceding brief summary is intended to call attention to only certain aspects of Applicants' invention that are relevant to the following discussion. The summary should not be viewed as encompassing all aspects previously disclosed and/or claimed, nor limiting the scope of Applicants' invention in any new manner.

III. Summary of the Cited Prior Art

A. The Chen Reference

The Chen reference describes a method to apply the List Viterbi Algorithm (LVA) to tail-biting convolutional codes (TCC). Thus, Chen is a combination of two known concepts: LVA and TCC. As is known in the art, for a TCC, the final state is the same as the initial state. Thus, the decoding process for TCC finds the best path for a given initial state where the final state is the same as the initial state. LVA generates a list of *L* best paths (and the corresponding transmitted data sequences) given a known initial state and a known final state.

In Chen, the first step is to identify the best pairs of initial/final states using either the standard Viterbi algorithm, or a suboptimal variation (Chen, col. 3, lines 6-13; lines 23-27). Typically, a conventional maximum likelihood decoder for TCC will execute a standard Viterbi algorithm *N* times where *N* is the number of states in the trellis. Each run corresponds to a specific pair of starting and terminating states.

The pairs (*L* pairs, or some number of best pairs less than *L*) are then examined to find a list of the best paths for each pair (Chen, col. 3, lines 28-30). The LVA is then executed for each of the *L* initial and final states. LVA operates in a manner similar to standard Viterbi decoding,

inasmuch as the error metrics are calculated for each interval, and candidate paths are extended from state to state, with a primary difference being that a number of best paths are retained at each time. Thus, each execution of the LVA generates another L paths and thus at the end of L executions of the LVA, L^2 paths are identified. All these paths are consolidated in one list and the best L paths from this list are presented as the output of the overall decoder. Thus, LVA of a TCC is achieved by Chen.

B. The Liu Reference

Applicants have reviewed the Liu reference, and have identified two pages that pertain to a high-speed Viterbi architecture. This architecture is called the higher-radix architecture whereby multiple trellis sections are processed in state-update step unlike conventional VA where one trellis section is processed in one state-update step. Thus, multiple bits can be decoded in one state-update. However, the branch metric unit (BMU) and the add-compare select (ACS) is made more complex.

IV. Response to the Office Action

A. The Figures

Applicants submit herewith a revised Figure 6, wherein the reference character "100" has been removed. With respect to the Examiner's requirement that the claimed step of "forming at least two groups of valid sequences" be depicted in the Figures, Applicants submit that such a step is shown at least in Figure 10A, and described in the specification in paragraph 0064 on page 30.

B. The Specification

Applicants have amended paragraph 58 in response to the Examiner's objection to state:

> Note that the CPI block 300 shown in Figure 8 operates first on the incremental error metrics $e_{sx}(n+1)$ generated from the most recent observations ~~first~~ (denoted as $r(n+1)$ ~~$r(n+2)$~~ in Figure 7 ~~8~~).

Applicants note that Figure 8 clearly shows the CPI block operating on the incremental error metrics, which are in turn generated from the observations as shown in Figures 6 and 7. Further, the CPI block 300 of Figure 8 operates *first* on the error metrics generated from the most recent observations, which in the case of the CPI block 300 of Figure 8 (generally corresponding to the CPI block 204 of Figure 6), are the incremental error metrics having a time index of n+1 (shown on the left side of Figure 8 as inputs to min-select devices 302, 304, 306, and 308). While more recent observations exist in the embodiment of Figure 6, they are used by other CPI blocks (e.g., 206, 208, and 210), and not the CPI block of Figure 8. This is also described in paragraph 66, on page 30 ("CPI block 204 operates on received samples $r(n-2)$ through $r(n+1)$ "). Applicants submit that no new matter has been added, as the amendment is clearly supported by the specification and Figures.

C. Response to the 102 Rejections

In the Office Action mailed March 13, 2006, the Examiner rejected independent claims 1, 9 and 25 under 35 U.S.C § 102(b) as being anticipated by Chen. The Examiner also rejected independent claims 13, 16, and 17 as being anticipated by Liu. Applicant respectfully traverses the anticipation rejections because the Examiner has not established that Chen or Liu teaches each and every element of any of these claims as would be required to support an anticipation rejection under M.P.E.P. § 2131.

Claims 1-8

Independent claim 1 was rejected based on Chen. As described above, the Chen reference applies the List Viterbi Algorithm (LVA) to Tail-biting Convolutional coding (TCC). Chen uses the observed data to first identify one or more pairs of initial and final states. The pairs are identified using traditional decoding schemes that operate on the received data, including the Viterbi algorithm or alternative suboptimal algorithms. Chen then applies the LVA to identify a list of possible paths for each pair. The lists are then combined into a global list which is then used for decoding.

The present invention, on the other hand, forms groups of sequences associated with the initial states without reference to any received data, observations, or other inputs. To clarify this aspect of the invention with respect to claim 1, the step of forming the groups of valid sequences has been amended to specify that the groups of valid sequences are "predetermined" and that the resulting groups contain "all possible valid sequences originating from the respective initial states". This step is not shown in Chen. Chen relies on Viterbi decoding or a variant thereof to identify a path for each initial/final state pair. From the pairs, the LVA algorithm is used to generate a list of alternative paths. Neither the initial paths nor the lists associated with the initial/final state pairs are predetermined lists, and neither includes all possible paths emanating from the initial state.

Applicants submit that claim 1 is allowable for at least the above reasons. In addition, the claims depending from claim 1 are also in condition for allowance, as they incorporate all of the limitations of the base claim.

Further aspects of the claims depending from claim 1 warrant further discussion in light of the Examiner's rejections. In particular, claim 2 is directed to an embodiment where the candidate paths are identified by selecting sequences "in time-reverse order." This aspect of the invention is described in various parts of the specification, including paragraphs 58 and 59, beginning on page 26 of the specification. In brief, the specification describes the identification of paths through the trellis in a time-reverse manner. That is, the channel observations and the associated error metrics are examined backwards to initially identify the paths. Chen, on the other hand, traverses the trellis in the standard fashion moving forward in time, and does not disclose any type of path identification in time-reverse order. The portions of the Chen cited by the Examiner relate to "tracing back" a path that has already been identified as a survivor to determine if it has merged with other paths, thereby permitting a decision to be made regarding the earlier symbols. This is a well-known aspect of the standard Viterbi algorithm, and does not relate to the recited element of claim 2, wherein the error metrics are used to generate accumulated path errors while moving through the trellis in a time-reverse manner.

With respect to claim 3, Chen fails to disclose the limitation: "candidate sequence selection information is fed forward from a prior output decision." As described above, Chen is

directed to block decoding, and hence the decoder does not utilize prior output decisions to make decoding decisions, much less use prior outputs to select a group and its associated candidate sequence. The Examiner stated that Chen discloses feeding prior output decisions forward to select a candidate path in Figures 4 and 5, and column 6, line 46 to column 7, line 20. Applicants have reviewed this portion of Chen, and submit that this portion of Chen merely discusses standard Viterbi decoding, including such aspects as: advancing through a trellis in the forward direction ("forward processing") by updating path metrics and selecting surviving paths; identifying surviving paths by considering the initial state, if known; truncating the decoding path by using a so-called decoding window; tracing back along the chosen path to determine the associated symbol decision information. None of these standard Viterbi techniques or any other content of Chen relates to making output decisions by selecting, based on prior output decisions, one of many previously identified candidate paths, where each of the candidate paths is associated with an initial state.

With respect to claim 4, the claim is directed to a multistage system where each stage identifies candidate paths and makes a decision based on candidate sequence selection information, and where "the at least one output decision of each stage is provided to at least one other stage as at least a portion of the candidate sequence selection information." Chen does not show a multistage system where the decision outputs of one stage are used to select a candidate path from another stage. The sections of Chen cited by the Examiner simply relate to Chen's method of selecting pairs of states, and the performing of LVA to obtain a list of paths. Nowhere does Chen suggest that actual output decisions from one stage are used to produce output decisions from another stage.

With respect to claim 8, Chen's passing reference to the use of soft decision decoding does not anticipate nor render obvious the particular use of soft information in the candidate path selection as described in claim 8.

Claims 9-12

Independent claim 9 was rejected as anticipated by Chen. Applicants submit that Chen fails to disclose the step of "forming sets of sequential samples of symbols, wherein the sets comprise at least a first set of samples and a next set of samples." The portions of Chen cited by the Examiner do not appear to relate to forming multiple sets of symbol samples. Rather, the sections appear to relate to: basic aspects of Viterbi decoding, including the determination of best paths, etc. (col. 1, lines 23-45); using the received sequence to identify the best path using various types of metrics (col. 5, lines 46-64); extending paths using path metrics to identify surviving paths (col. 6, lines 7-24); making decoding decisions based on the surviving paths (col. 6, lines 46-65); utilizing LVA to identify lists of paths (by trimming paths) which may then be used by a CRC decoder for error detection (col. 8, lines 53-68); error detection schemes using only LVA by comparing differences in the metrics to a threshold (col. 10, lines 3-9); and, optimum decoding of a block of data to obtain the best paths between pairs of identical starting and terminating states (col. 11, lines 17-57). Nowhere is there a mention of forming two sets of sequential samples.

In addition, Chen fails to teach that such sets are used to determine "a plurality of minimum error paths" for the groups of paths through a trellis. The Examiner has cited "figure 11, block 1110 path metrics column 11 line 41 to column 12 line 13" as meeting this limitation.

However, Figure 11, block 1110, of Chen, and the portions of column 11 and 12 cited by the Examiner, describes the use of the best paths corresponding to starting state "Sa" and termination state "Ta", (and other pairings, Sb-Tb, through Sl-Tl), and applying the LVA to generate the list of paths for that state pair. This does not relate to the use of separate sets of samples as claimed, but appears to operate on the single set of observations for the entire block of data being decoded.

Similarly, as described above with respect to claim 3, Chen does not disclose the step of selecting decision information "where the selection is based on prior state information". The citations to Chen provided by the Examiner do not disclose any selections of decision information using prior state information.

Finally, Chen does not disclose the element of "using at least a portion of the selected corresponding decision information to select a group corresponding to the next set of samples and its corresponding decision information." As described above, Chen does not disclose the use of separate sets of samples for any of the above recited functions, much less the final step of using decision information generated from one set of samples to select decision information from paths identified using the second set.

For the reasons set forth above, applicants respectfully submit that claim 9, and those claims depending therefrom are not anticipated by the Chen reference, and are in condition for allowance.

Claims 13-24

Independent claims 13, 16, and 17 are directed to a decoder apparatus. The Examiner rejected these claims under 35 U.S.C § 102(b) as being anticipated by Liu. Liu depicts standard Add-Compare Select (ACS) units that are used to compare paths by adding a branch metric to the accumulated path error, and select the better path. Liu also describes a modified look-ahead ACS unit that can identify the best of four possible paths based on the relevant branch error metrics. That is, the branch metrics (BM) are added to the accumulated path metrics (PM) by the "adder" blocks, and the results are compared by a "compare" block, which provides an output to select a survivor path via a "mux" block. Two such survivor paths are compared by an additional "compare" block, which controls another "mux" block to select the best of the four paths. Thus, the structures of Liu may be used to identify the best paths through a trellis in a more pipelined fashion.

While Liu discloses a system that uses adders, comparators and selectors to identify survivor paths, the claimed invention relates to hardware that not only identifies candidate paths but then provides those paths, and the associated decision information to a selector, the output of which is the decoding decision. Claim 13 includes a "sequence error estimator" that identifies candidate paths (and the associated decision information), and provides the decision information at "candidate path outputs" in combination with a "selector" connected to the sequence error estimator. The selector receives the "candidate path outputs" and provides one of them at its selector output, in response to a "selection input." Liu does not disclose any method or structure relating to such a selector.

In particular, the selector of claim 13 has as inputs the possible decoded decision information from the candidate paths that have already been identified. The output of the selector is the decision information provided by one of the inputs. Liu does not have any selector that provides decision information at its output. Rather, the "mux" units of Liu are simply providing the path metrics of the surviving paths, not decision information.

Independent claim 16 is similar to claim 13, but recites a parallel structure for the decoding that includes a plurality of candidate path identification blocks and a plurality of selection devices. The selection devices operate as described above, but the claim further recites that "the data outputs of each of said plurality of selection devices is used to select the data outputs of another of said plurality of selection devices." Independent claim 17 similarly recites that the selecting means provides output decision information that is generated in response to "output decision information from a selecting means of another decoding means." Thus, both of these independent claims are directed to a device that provides output decision information from a selector. Liu's structure is used to identify survivor paths, and does not describe a selector that receives candidate path decision information and provides an output corresponding to one of the inputs.

Applicants respectfully submit that independent claims 13, 16, and 17 are in condition for allowance, as are all the claims depending therefrom, including claims 14, 15, and 18-24.

Claims 25-30

With respect to independent claim 25, Applicants submit that Chen does not disclose the combination of the recited claim, which includes (i) identifying a candidate sequence for each initial state of a system having a plurality of initial states, wherein each candidate sequence has an associated candidate set of decision information; (ii) receiving initial state decision information; and (iii) selecting a single candidate set of decision information from the candidate sets in response to the received initial state information.

In particular, Chen does not select a candidate sequence or associated decision information in response to the initial state information. As described above, Chen is directed to block decoding, and hence the decoder does not utilize prior output decisions to make decoding decisions, much less use prior outputs to select a group and its associated candidate sequence.

With respect to claim 26, Chen does not describe time-reverse path/sequence identification. The trace back mechanism of Chen is the well-known aspect of standard Viterbi decoding where paths that have already been identified as the "best" paths are examined to see if they all initially emerge from the same state. Importantly, those paths were obtained through forward traversal of the trellis, not time-reverse traversal, as claimed.

Claims 27-30, being dependent upon claim 25, are allowable for the reasons set forth above regarding claim 25.

D. Response to the 103 Rejections

With regard to the § 103 rejections of claims 5, 7, 10, 12, 23, and 29, Applicants have reviewed the remaining references and have not identified any material that makes up for the deficiencies with respect to the Chen and Liu references as detailed above. Therefore, Applicants submit that the remaining dependent claims are allowable for at least the reasons identified above with respect to the independent claims.

CONCLUSION

The Applicants submit that the application is in good and proper form for allowance and respectfully request the Examiner to pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of this application, the Examiner is invited to call the undersigned attorney, at 312-913-3305.

Respectfully submitted,

McDONNELL BOEHNEN
HULBERT & BERGHOFF LLP

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By: Robert J. Irvine III

Robert J. Irvine III
Registration No. 41,865